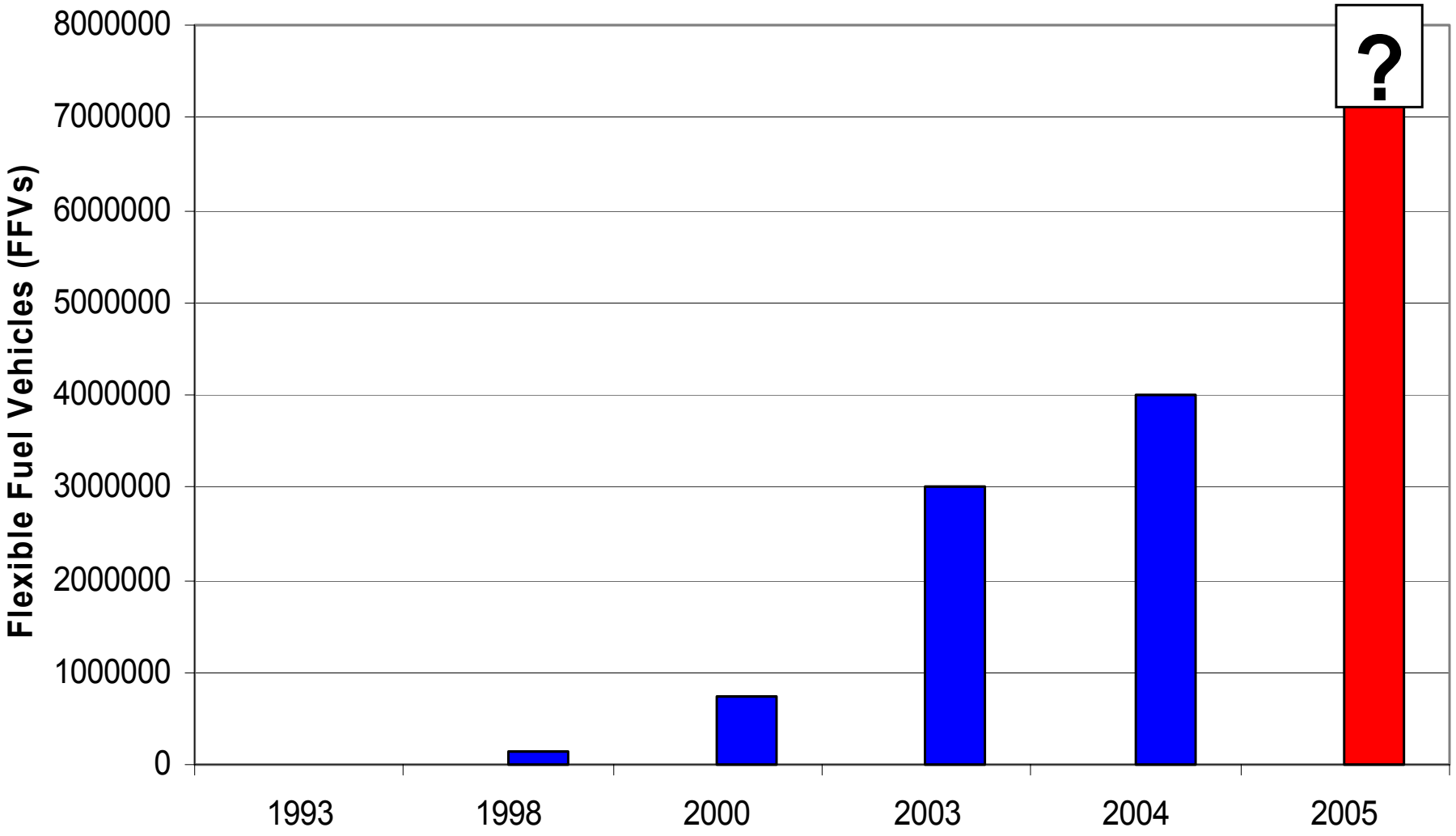
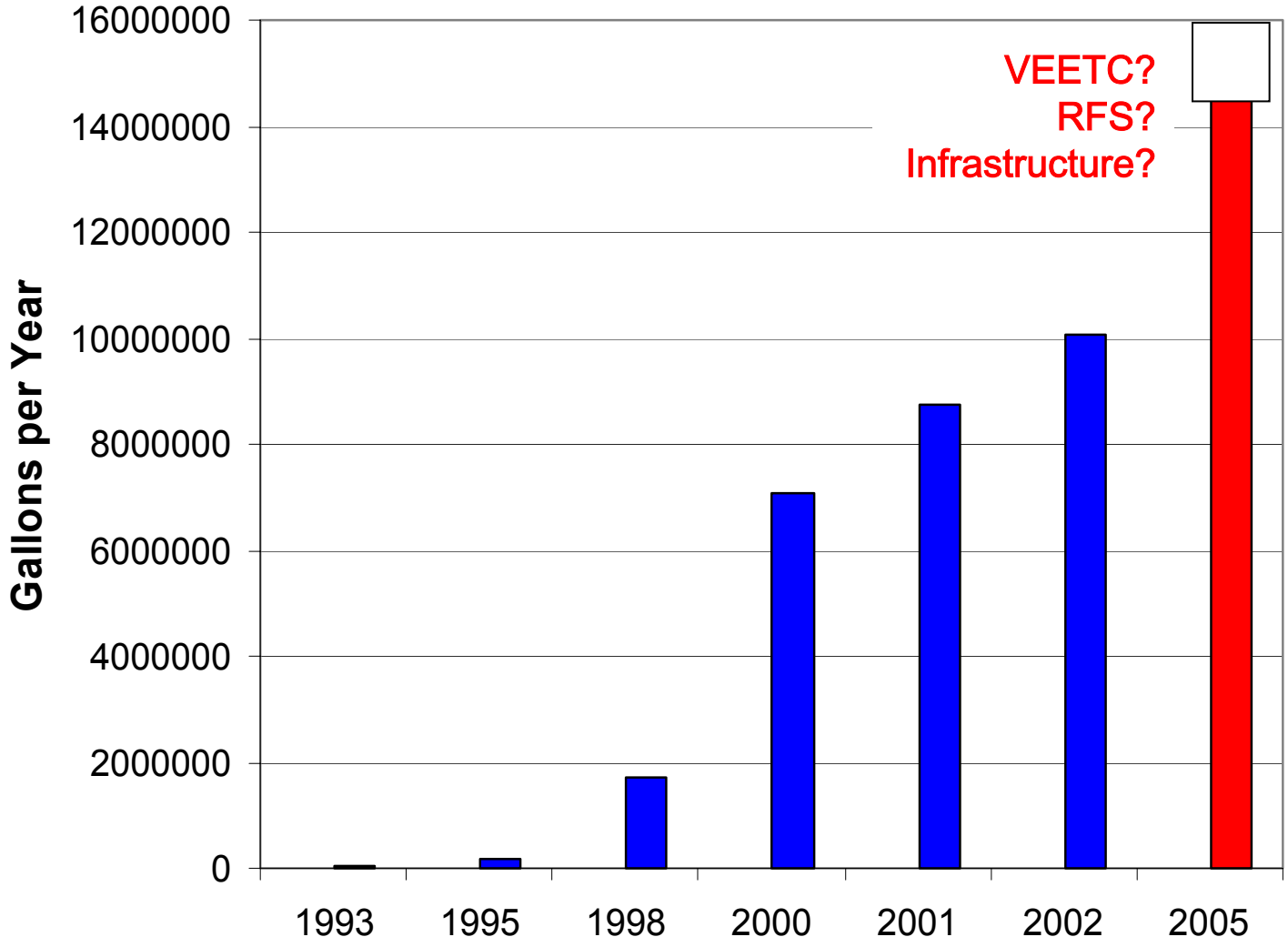
E85 FFV Availability

- Current California fleet consists of approximately 200,000 E85 FFVs, with 30,000 additional FFVs added per year
- Beginning in 2005, GM will make FFVs available in California, adding 45,000 FFVs per year
- Estimate 275,000 FFVs in the California fleet in 2005
- Future California emission requirements are likely to limit the availability of E85 FFVs beyond 2007 as PZEVs are sold to meet the ZEV mandate
- New technology to eliminate the ethanol fuel line sensor may reduce cost of FFV capability

Estimated Total FFV Population in the United States



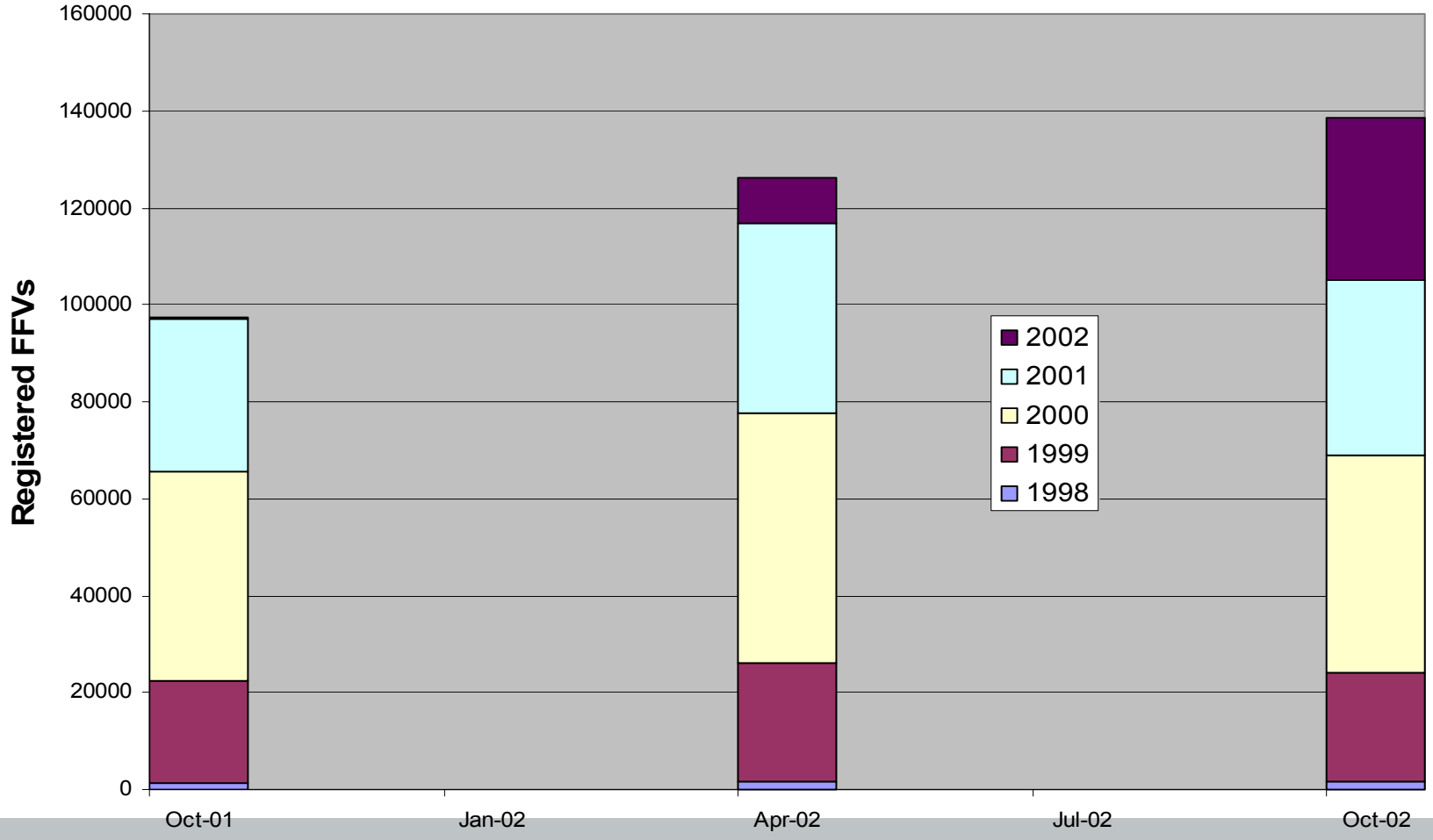
E85 Growth in the United States



E85 FFV Availability

- **Continued incentives are needed to insure availability of FFVs beyond 2008**
- **Emission regulations and FFV incentives issues make 2010 and later estimates difficult**
  - **BAU 450,000 in 2008-2010, 420,00 in 2015, 300,000 in 2020**
  - **AG 600,000 in 2010, 850,000 beyond 2010**
  - **AG requires resolution of emissions and vehicle incentive issues**

Growth in California FFV Population by Model Year



Source: California Energy Commission

California Regulatory Opportunities

- **Clean Fuel Program triggering provision in California regulations (13 CCR 2303.5 – 2004)**
  - **20,000 FFVs would trigger retail clean fuel outlet requirement (fleet vehicles are discounted by 75%)**
  - **Number of FFVs in the current fleet exceeds this level by 10x, and are likely to maintain it beyond 2010**
  - **GM alone will exceed this level in 2005 MY**

Ethanol Supply & Availability Research

- Gasoline usage in the US is approximately 140B gal/yr, 130B gal/yr is consumed by the light duty fleet
- Maximum amount of ethanol produced from corn is thought to be limited to approximately 15B gal/yr due to loss of value in co-products
- Commercial ethanol production from cellulose is just beginning (logen announcement April 2004)
- Ethanol production potential from biomass is currently under investigation
- The current cost of cellulose derived ethanol is $1.33 per gallon, but is expected to decline to as low as $.76 per gallon through advances in technology

Basis of estimates: Dr. Heather McLean, University of Toronto
GM funded research and GM R&D Center

Ethanol Supply and Availability Research

- Biomass sources include agricultural waste, energy crops and municipal solid waste
- In the long term, based on current practical estimates, cellulose-derived ethanol plus corn ethanol could displace 50B gal/yr of gasoline, supplying 25% - 30% of the light duty fleet requirements on an energy equivalent basis
- This assumes improved biomass yields, advancements in cellulose ethanol production technology, and appropriate subsidies

Biomass Ethanol Industry Examples

Iogen (Ottawa, Canada)

- Demonstration facility (40 tonnes feedstock/day)
- Considering construction of a 60 M gal/yr plant 4Q 2004
- Wheat straw, dilute acid pretreatment, an enzymatic hydrolysis (*T. reesei*), genetically engineered microbe (*Z. mobilis*)

Arkenol (Sacramento, California)

- 100 (500) ton/day facility (4 (20) M gal/yr) - final financing
- Rice straw, two-step concentrated acid, yeast (S*. cerevisiae*)

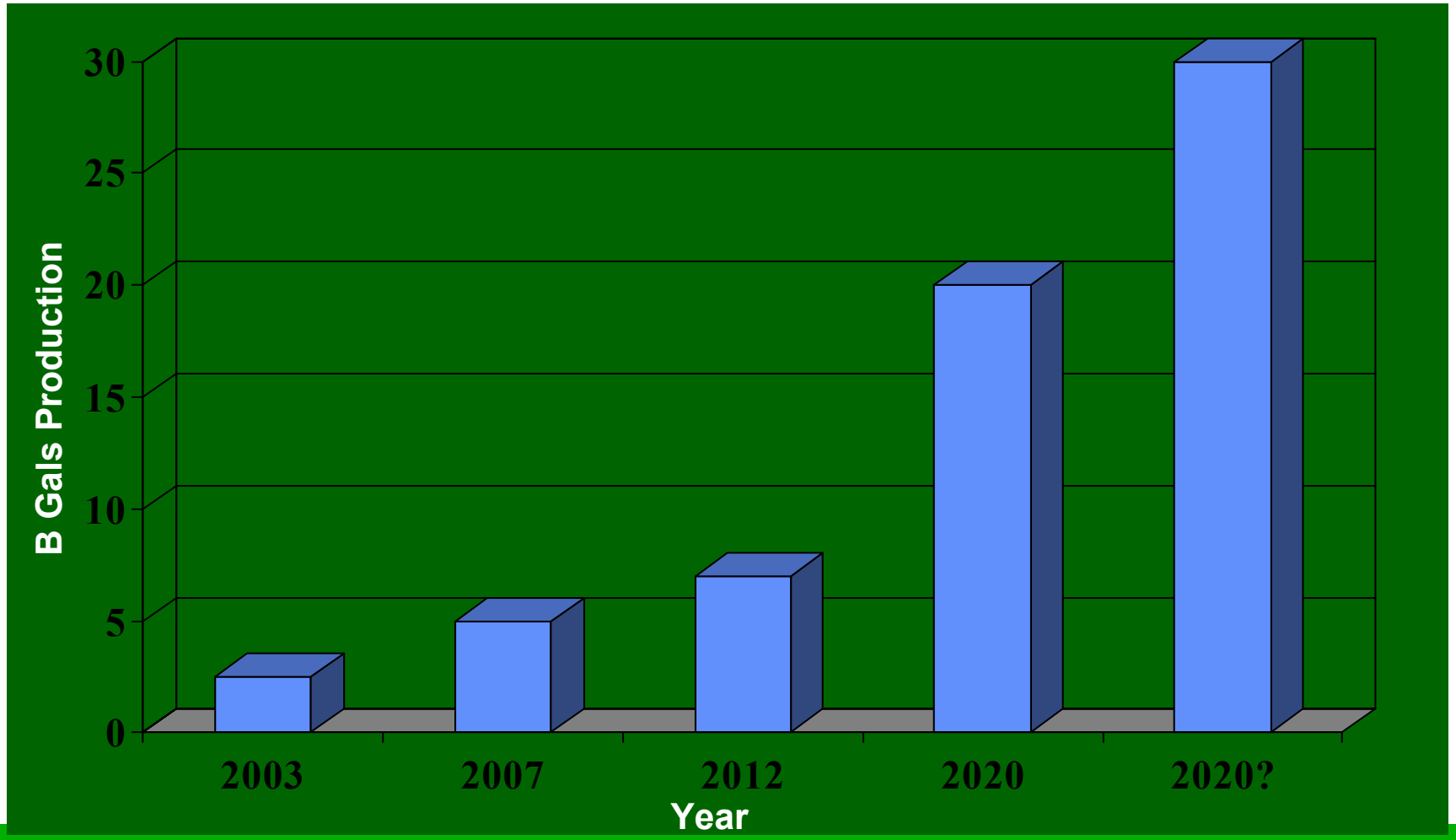
BCI (Jennings, LA, Gridley, CA, Chester, CA)

- 23 M gal/yr 3Q 2004, 25 M gal/yr 2Q 2005, 20 M gal/yr
- Bagasse, rice straw, mill wood wastes, dilute acid, KO11 (Ingram *E. coli* bacteria)

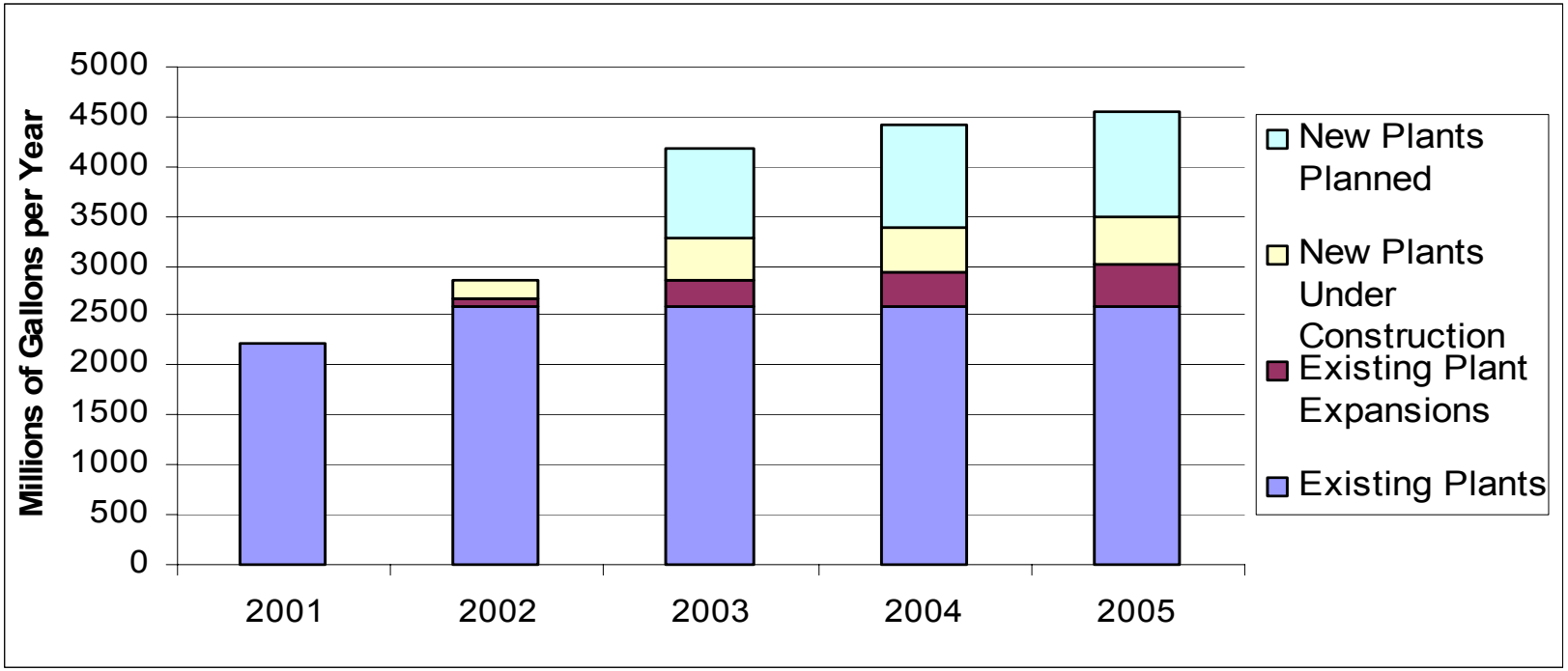
Masada (Middletown, New York)

- 850 ton/day (9.5 M gal/yr) 1Q 2005 with 90% less landfill
- Municipal solid waste, concentrated acid

National Renewable Energy Laboratory Projections of Future Ethanol Production



2002 US Ethanol Production Capacity and Forecast



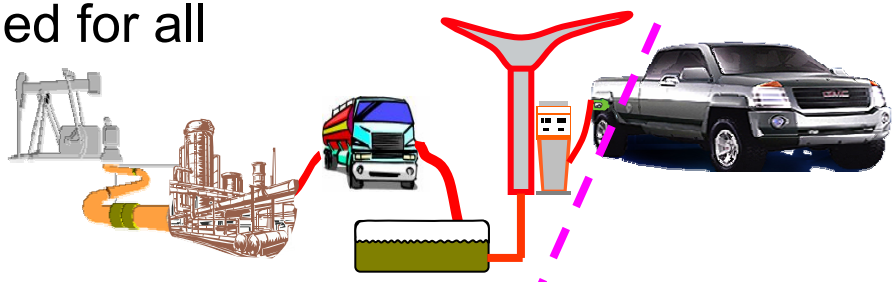
Source: California Energy Commission

California Ethanol Supply Projection

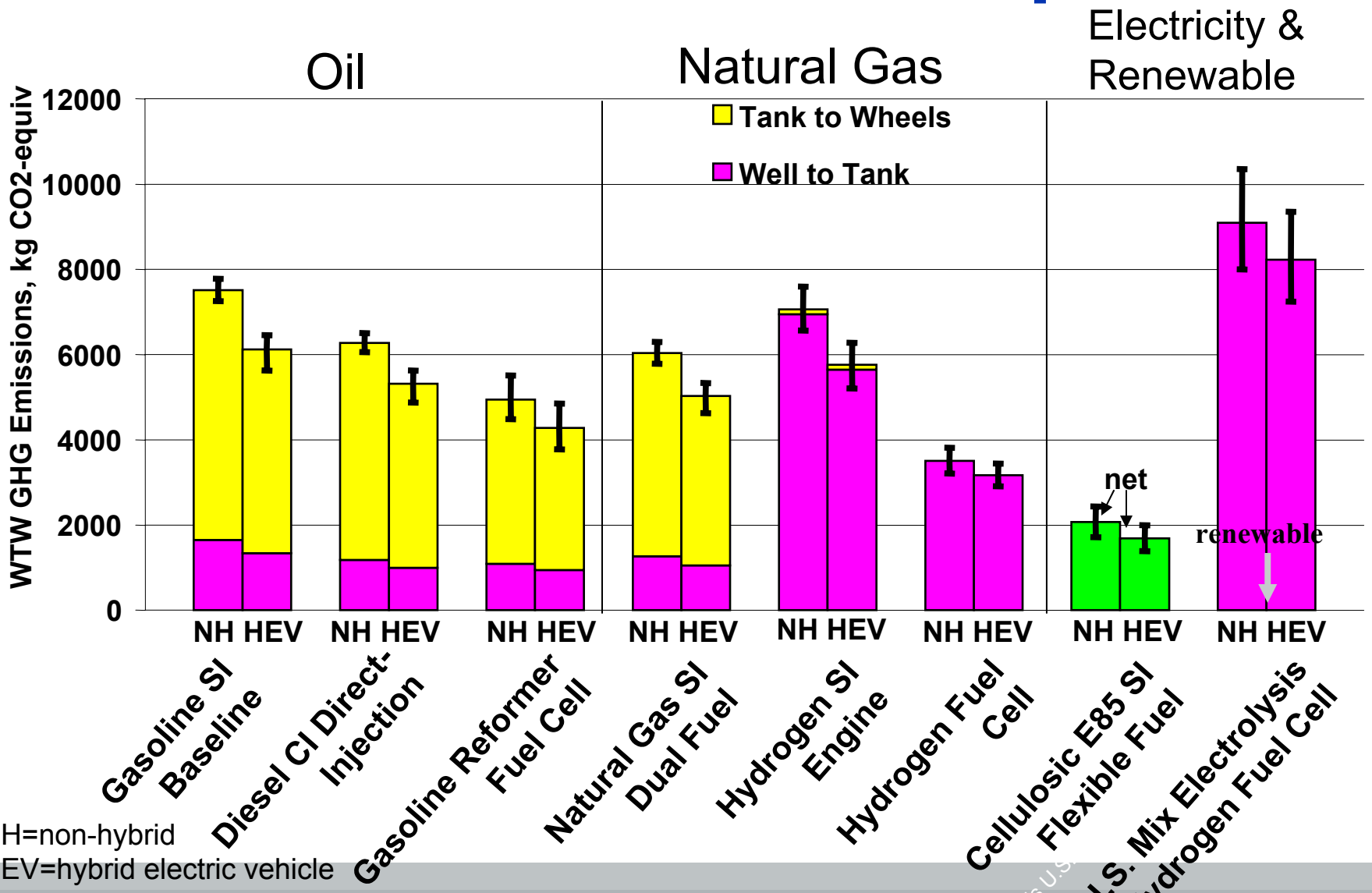
- California gasoline useage approximately 16.5B gal/yr, or 11.8% of US gasoline use
- Estimated California portion of plausible US ethanol supply from corn + cellulose = 6B gal/yr on an energy equivalent basis
- Approximately 5B gal/yr of gasoline displaced
- As with US estimates, assumes improved biomass yields, advancements in cellulose ethanol production technology, and appropriate subsidies
- Long term time frame
- BAU estimate 1B gal/yr
- AG estimate 6B gal/yr gasoline displaced 2015-2020

GM Well-to-Wheels Analysis

- Systems approach
- Predicts energy consumption and emissions of VOC, CO, NOx, PM10, SOx, and greenhouse gases
- GM sponsored the study and conducted the modeling of vehicle fuel consumption and greenhouse gases
- Partners in the well-to-wheels effort were:
  - Argonne National Laboratory (Well to Wheels)
  - Air Improvement Resource (Vehicle Emissions)
  - Eastern Research Group (Stationary Source Emissions)
  - Advanced Development Corporation (Vehicle Fuel Economy Modeling Support)
- Equal performance maintained for all propulsion systems



Well-to-Wheels Annual Greenhouse Gases per Vehicle



NH=non-hybrid
HEV=hybrid electric vehicle

Opportunities

- Increased use of ethanol in transportation fuel in California could address reduced petroleum fuel use and vehicle CO2 emissions targets.
- Research on cellulose ethanol production suggests that ethanol has the potential to attain the petroleum fuel use reductions recommended in the CEC IEP Report.
- Increased use of ethanol in transportation fuel in California may be an achievable method to reduce vehicle CO2 emissions.

Barriers

- FFV availability beyond 2008 due to vehicle emissions and incentive issues
- Reduced vehicle range on E85, lower “miles per gallon”
- E85 infrastructure development
  - Ethanol distribution
  - Wide distribution of retail outlets
- Ethanol supply development
  - Maximize corn ethanol supply
  - New bio-mass ethanol industry

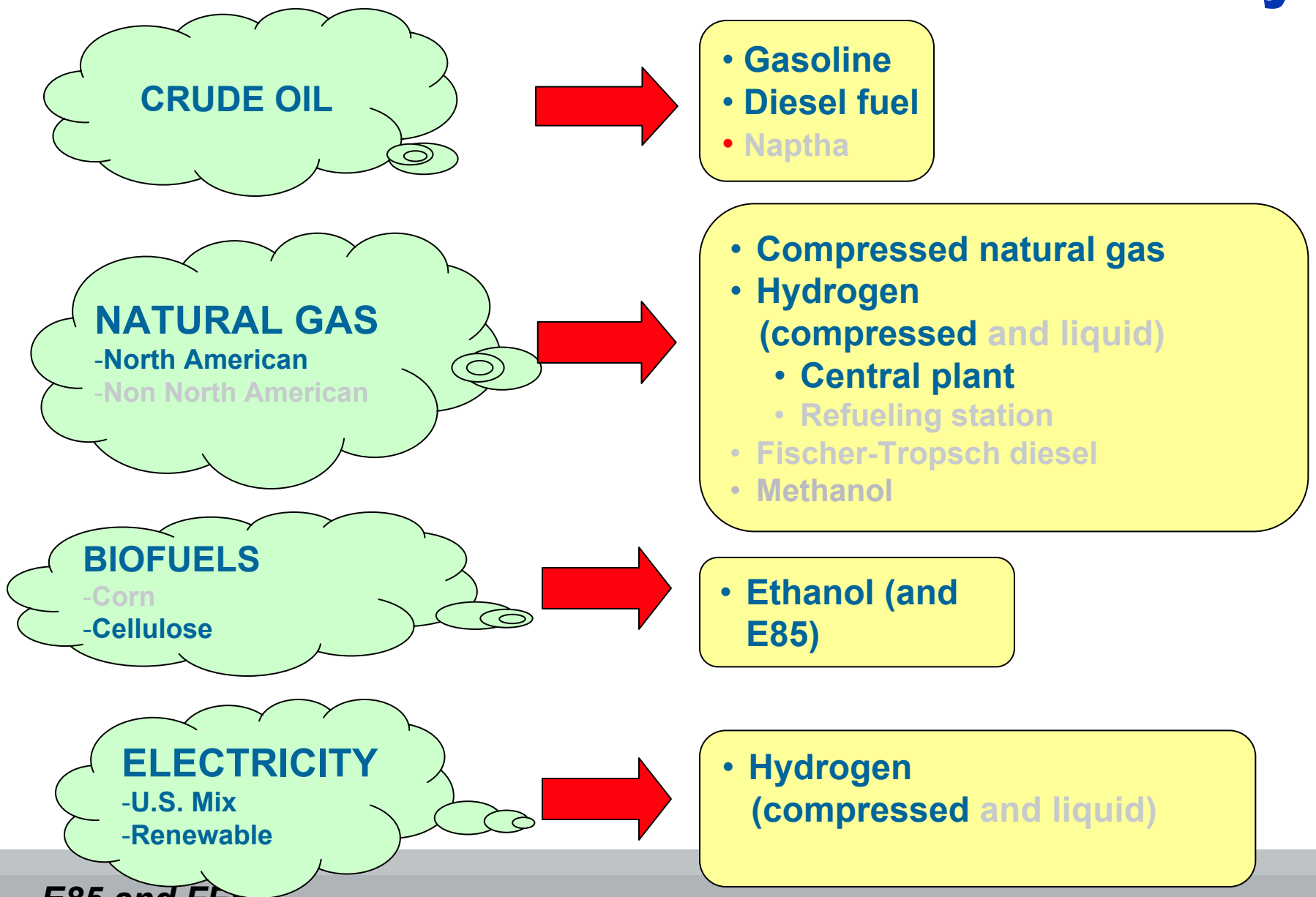
Barriers

- Advancements in cellulose ethanol production technology
- Availability of incentives
- Definition of “complying” E85
- Criteria pollutant emissions from ethanol production

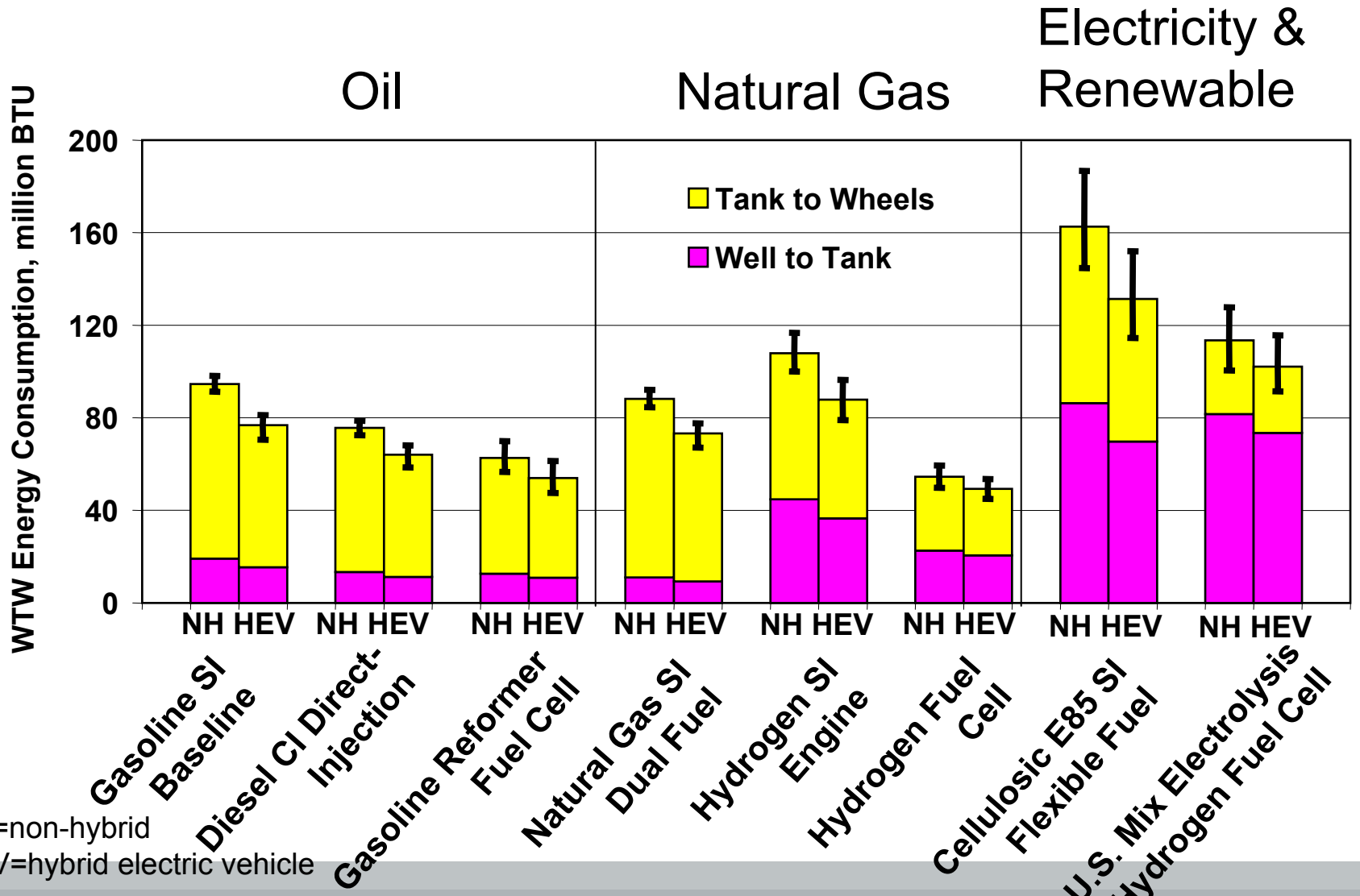
Vehicle Propulsion Systems Analyzed

	IC Engine	IC Engine Hybrid	Fuel Cell	Fuel Cell Hybrid
Gasoline	X	X	X	X
Diesel	X	X		
F-T Diesel	X	X		
CNG	X	X		
Methanol			X	X
Ethanol	E85	E85	E100	E100
Hydrogen	X	X	X	X

Fuel Pathways

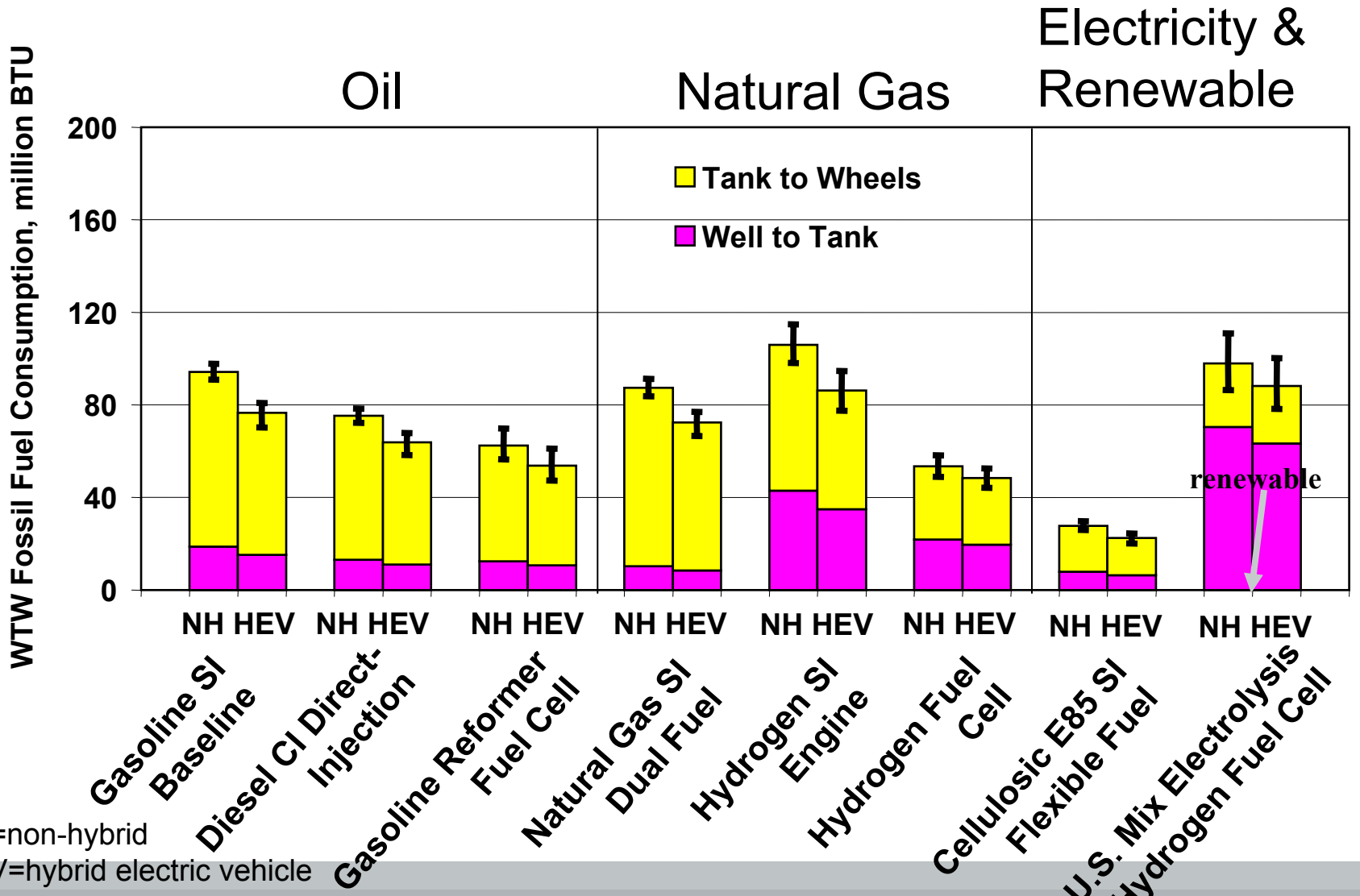


Well-to-Wheels Annual Energy Consumption per Vehicle



NH=non-hybrid
HEV=hybrid electric vehicle

Well-to-Wheels Annual Fossil Fuel Consumption per Vehicle



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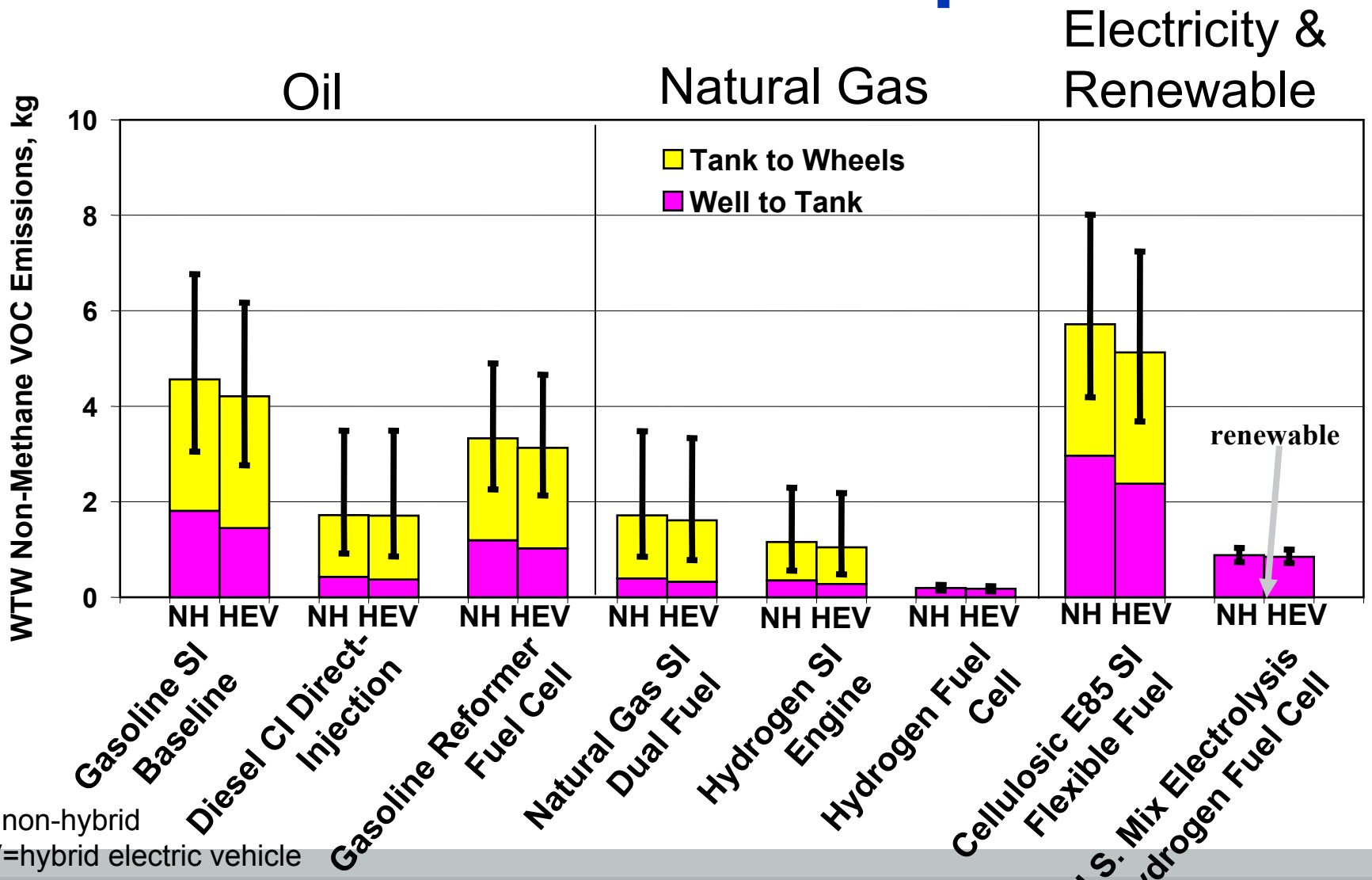
HEV=hybrid electric vehicle

Well-to-Wheels Annual VOC Emissions per Vehicle



NH=non-hybrid
HEV=hybrid electric vehicle

Conclusions for Greenhouse Gas Emissions

- Well-to-Wheels greenhouse gases can be significantly reduced with the following (ordered by increasing impact):
  - Advanced gasoline and diesel engines and hybrids
  - Fuel cells with hydrogen from natural gas
  - Cellulosic ethanol in internal combustion engines
  - Fuel cells with renewable electricity used to produce and compress hydrogen

Policy Issues/Questions

Could 25% of CA vehicles be FFVs in 10 years?

- **Federal/state production incentives**

Would adoption of federal/state incentives advance infrastructure development?

Will federal/state ethanol incentives be retained?

Will state develop indigenous ethanol production program?

Will a domestic/renewable fuel be used for hybrid and fuel cell vehicles?

Will ethanol based fuels be recognized as a CO2 reduction strategy?